Chapter 5

Pipe Design

CHAPTER 5 PIPE DESIGN

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CHAPTER 5

PIPE DESIGN

5.1 GENERAL

There are several types of pipe that may be used in stockwater systems. The most commonly used types are discussed below. Usually, price per foot of pipe dictates the type of pipe that is used.

When designing a pipeline, it is important to know the type of pipe to be used. Internal pipe diameters vary depending on material type and pressure rating for a given nominal pipe size. Due to differing internal cross sectional area, and differing friction loss factors, friction loss in long pipelines can differ considerably from one type and rating of pipe to another.

Many plastic pipes are specified as having an SDR (Size Dimension Ratio) or DR (Dimension Ratio). For these pipes, as SDR or DR increases, the pipe's wall thickness decreases. For Outside Diameter (OD) controlled pipes, SDR = average OD/minimum wall thickness. For inside diameter(ID) controlled pipes, DR = average ID/minimum wall thickness.

5.2 PLASTIC PIPE CHARACTERISTICS

5.2.1 Pressure Rating of Pipe

Plastic pipe is rated at approximately half its tested rupture strength. This means that under normal temperature conditions, it can withstand occasional surge pressures up to twice its rated pressure. If the surge pressure is not calculated, which is usually the case in Missouri, limit the maximum pressure on the pipe to 72% of it's pressure rating (PR). This is an industry accepted method (ASAE S376.1). See tables 5.1, and 5.2 for maximum allowable pressure for PVC and PE.

$$PR = \frac{2f}{SDR-1} \quad \text{(Outside Diameter Controlled)}$$

$$PR = \frac{2f}{DR+1} \quad \text{(Inside Diameter Controlled)}$$

PR= Pressure Rating
f= Hydrostatic Design Stress (See TR-77)

Plastic pipe will weaken under repeated cycles of pressures in excess of those for which it is rated. The higher the surge pressure the faster the pipe will weaken. For this reason it is important to design the pipe system so that normal operating pressures are less than rated pressure of the pipe. The system should be designed and operated to limit the number and severity of pressure surges. Other sections of this manual describe ways to limit surge pressures.

Table 5.1
MAXIMUM ALLOWABLE PRESSURE (psi) FOR NONTHREADED PVC WHEN SURGE PRESSURES ARE NOT KNOWN ASTM-D-2241 SDR-PR, OD BASED

	PVC Material (OD based)			
SDR	PVC 1120 PVC 1220 PVC 2120	PVC 2116	PVC 2112	PVC 2110
13.5	227	180	144	115
17.0	180	144	115	90
21.0	144	115	90	72
26.0	115	90	72	58
32.5	90	72	58	45

Maximum allowable pressure = 72% of the PR for SDR and DR pipe @ 73.4 degrees F.

Table 5.2
MAXIMUM ALLOWABLE PRESSURE (psi) FOR NONTHREADED PE WHEN SURGE PRESSURES ARE NOT KNOWN

		PE Material (OD & ID based)		
SDR		PE 3408	PE 3406 PE 3306 PE 2306 PE 2406	PE 2305
OD based	ID based			
	5.3	180	144	115
	7.0	144	115	90
11.0	9.0	115	90	72
13.5	11.5	90	72	58
17.0	15.0	72	58	45
21.0		58	45	
26.0		45	36	
32.5		36	29	

Maximum allowable pressure = 72% of the PR for SDR and DR pipe @ 73.4 degrees F.

5.2.2 How Temperature Affects Pressure Rating

The pressure rating of plastic pipe is determined at 73.4 degrees Fahrenheit (F). Strength of plastic pipe decreases as water temperature becomes warmer. In cases where warm well water is used, or where there is pipe exposure, water temperatures may exceed 73.4 degrees F. In that case, effective pressure rating of the pipe must be reduced.

Table 5.3 lists the temperature reduction factors for PVC pipe.

Table 5.3
PVC PLASTIC PIPE RATING REDUCTION DUE TO TEMPERATURE

Temperature Degrees F	Multiply Pressure Rating by:
73.4	1.00
80	.93
90	.77
100	.67
110	.51
120	.43
130	.33
140	.23

5.2.3 Freezing of Water in Pipe

Plastic pipe containing static water should be drained when temperatures below 32 degrees F are expected. If the water is moving, freezing is unlikely above 0 degrees Fahrenheit.

If freezing does occur in the line, the pipe material will influence whether the pipe is damaged. In changing phase from liquid to ice, water expands approximately 10% by volume. Some plastic pipe will not survive the required 3.2% linear elongation, but most will.

Pipes most likely to be damaged by freezing water are those made of rigid materials, which include PVC and CPVC.

Pipe most unlikely to be damaged by freezing water include the cellulose-aceto-butyrate, acrylonritrile-butadine-styrene, styrene rubber, and polyethylene materials. All of these pipes have elongation and recovery properties which should in most cases enable it to expand and recover without permanent damage.

Although some pipe material can usually withstand freezing without damage, no system should be knowingly designed to freeze while full of water. Resistant pipes can be used in areas of severe exposure as an extra safety factor against damage by freezing. An excellent example of this is a shallow pipeline leading from a spring.

5.3 POLYVINYL CHLORIDE (PVC) PLASTIC PIPE

Polyvinyl Chloride (PVC) is a commonly used type of pipe used for stockwater pipelines. This is a rigid plastic pipe that, in the configuration used for stockwater pipelines, usually comes in 20-foot lengths. Connections are usually made with glued fittings, although rubber gasketed joints are sometimes used.

When subject to long-term exposure to ultraviolet radiation (sunlight), PVC pipe will suffer slow deterioration. PVC pipe should be buried or installed in an enclosure. If PVC must be exposed it should

be coated or wrapped. The coating may be exterior latex paint. Make sure the pipe is thoroughly cleaned before painting.

Exposed pipe should be protected from mechanical damage by livestock or other hazards. Plastic pipe is particularly vulnerable when cold, as it will easily shatter.

There are two types of PVC pipe used in pressure pipelines. Standard Dimension Ratio-Pressure Rated pipe (SDR-PR) is manufactured under specification ASTM D2241. PVC Iron Pipe Size (PVC-IPS) pipe (eg. Schedule 40) is manufactured under specification ASTM D1785.

SDR-PR rated pipe is rated using standard dimension ratio (SDR) and pressure as factors. SDR equals average outside diameter divided by minimum wall thickness. Wall thickness increases as SDR value decreases. Tables 5.4**,** 5.5**,** 5.6 and 5.7 list available sizes, pressure ratings and friction loss factors.

PVC-IPS has the same outside diameter as iron pipe. It has various pressure ratings depending on nominal diameter**,** schedule and material (eg. PVC 1120) designations. Schedule 40, 80, and 120 pipe are available. Out of the three schedules, Schedule 40 is most commonly used in Missouri. Tables 5.8 and 5.9 list available sizes, pressure ratings, and friction loss factors.

For both of these types of pipe, the outside diameter is constant and the inside diameter varies.

Both PVC-PR and PVC-IPS are available in different pressure ratings (PVC material). Type I, Grades 1 and 2 are designated PVC1120 and PVC1220, respectively. The following materials are designated for Type II, Grade 1; PVC2120, PVC2116, PVC2112 and PVC2110. Check with your local supplier for availability of the material designation (eg. PVC2120), ASTM specification (eg. ASTM-D-2241) as well as the SDR or schedule for pipe sizes needed. These variables are important to know before friction loss can be accurately calculated.

Three specifications cover low pressure PVC pipe that can be used in gravity systems: ASTM-D-2665 (PVC, 1-1/4" to 12"), ASTM-D-2729 (PVC Sewer Pipe, 2" to 6") and ASTM-D-3034 (PVC Type PSM, 4" to 15").

5.4 POLYETHYLENE (PE) PLASTIC PIPE

Polyethylene (PE) pipe is another commonly used pipe in stockwater pipelines. It is flexible, comes in coils and is used for most "pull-in" type systems. Where pipe is installed in trenches, it is harder to lay flat in the trench than PVC pipe. Since it comes in coils, PE pipe takes fewer fittings to lay. Connecting this type of pipe is usually done with "stab" type fittings held together with stainless steel band clamps. Frost heave in shallow pipelines tends to pull these joints apart. Double clamping is usually necessary to combat this problem and is reccomended in Missouri.

There are several types of PE pipe. The one most commonly used in stockwater pipelines is a controlled inside diameter version rated by standard thermoplastic dimension ratio and pressure rating (SIDR-PR ID Controlled) and is manufactured under specification ASTM D2239. SIDR 15, 100 psi pipe is usually the most available polyethylene pipe. Less common types include; ASTM-D-2104 (PE, Schedule 40), ASTM-D-3035 (PE, SDR-PR, OD Controlled), ASTM-D-2447 (PE Schedules 40 and 80, OD Controlled), ASTM-D-2737 (PE) and ASTM-F-771 (PE). Polyethylene (PE) pipe conforming to AWWA C901 is readily available.

Table 5.10 shows available sizes, pressure ratings, and friction loss factors.

A high density polyethylene pipe (HDPE) is available which can be used for above ground installations. This is the same type of pipe as used in hose reel type irrigation sprinkler systems. The material is tough, will withstand long term exposure to sunlight and may be used above ground where below ground installations are not possible. When used above ground it must be tied down so it will not pull apart and it must be protected or placed in a manner which will prevent mechanical damage. HDPE is available in sizes 1/2 inch and larger.

This material is tough, flexible, and resistant to freeze damage. Although sometimes proposed for shallow non-drained pipelines, it should not be used in this way. This pipe will usually withstand freezing without damage, but the system should not be knowingly designed to freeze while water is in the line.

5.5 ACRYLONITRILE-BUTADIENE-STYRENE (ABS) PLASTIC PIPE

Although listed in the standards as an acceptable pipe material, ABS pipe is used little in the transmission pipeline portions of stockwater pipelines. ABS pipe is frequently used in stockwater systems as drain, vent, and waste system components. This black pipe has the advantages of being tough with good strength and stiffness. It is not tolerant to ultraviolet light, so it should be painted or wrapped if exposed to sunlight. It ranges in size from 1/8-inch to 12 inches in diameter. Types of ABS include; ASTM-D-1527 (ABS Schedules 40 and 80), ASTM-D-2282 (ABS, SDR-PR). However, ABS pipe and their fittings may not be available in Missouri.

5.6 POLYBUTYLENE (PB) PLASTIC PIPE

Polybutylene pipe, is sometimes used in household plumbing and underground water service. However, it is no longer available in Missouri.

This material is tough, flexible, and resistant to freeze damage. Although sometimes proposed for shallow non-drained pipelines which freeze in the winter, it should not be used in this way. This pipe will usually withstand freezing without damage, but the system should not be designed to freeze with water in the line.

5.7 STEEL PIPE

Steel pipe is often used in system plumbing next to the pump. It is rarely used in main parts of the pipeline in buried installations.

Steel pipe is used in buried applications only as a last resort due to its high cost, high friction loss, and because it easily corrodes. If corrosion is a problem heavier threaded PVC pipe, schedule 80 or 120 may be beneficial.

Galvanized pipe should be used for exposed installations such as at cable supported aerial stream crossings, and as plumbing in manholes. When buried, steel pipe should always be coated and wrapped. This is due to the corrosive nature of most soils.

Some water in Missouri is highly corrosive. When long sections of steel pipe are used which cannot be easily replaced, then a sample of the water supply should be taken and a Langelier Index run on the sample. If the test shows the water to be highly corrosive, unlined steel pipe should not be used. Analysis by the Langelier Index is beyond the scope of this manual and should be referred to State or

Area Engineering staff with knowledge of its use. Steel pipe connected to brass or bronze fittings will corrode at a faster rate.

Occasionally, steel pipe must be used for very high pressure pipelines where plastic pipe is not available with adequate pressure ratings. Operating pressures in steel pipe should not exceed 50 percent of the rated bursting pressure.

5.8 FRICTION LOSS IN PIPING SYSTEM AT THE PUMP

Friction losses in the plumbing at the pump is significant enough that it should be considered when determining total dynamic pumping head. The typical pipe material used between a submersible pump and pressure tank is polyethylene pipe with some steel pipe at the pressure tank. High pressure systems sometimes use steel pipe between pump and pressure tank.

The plumbing elements for an automatic pressure system and a manual or timed system are about the same. Figure 5.1 is a graph which shows estimated friction loss values that can be used for most pumped flow installations.

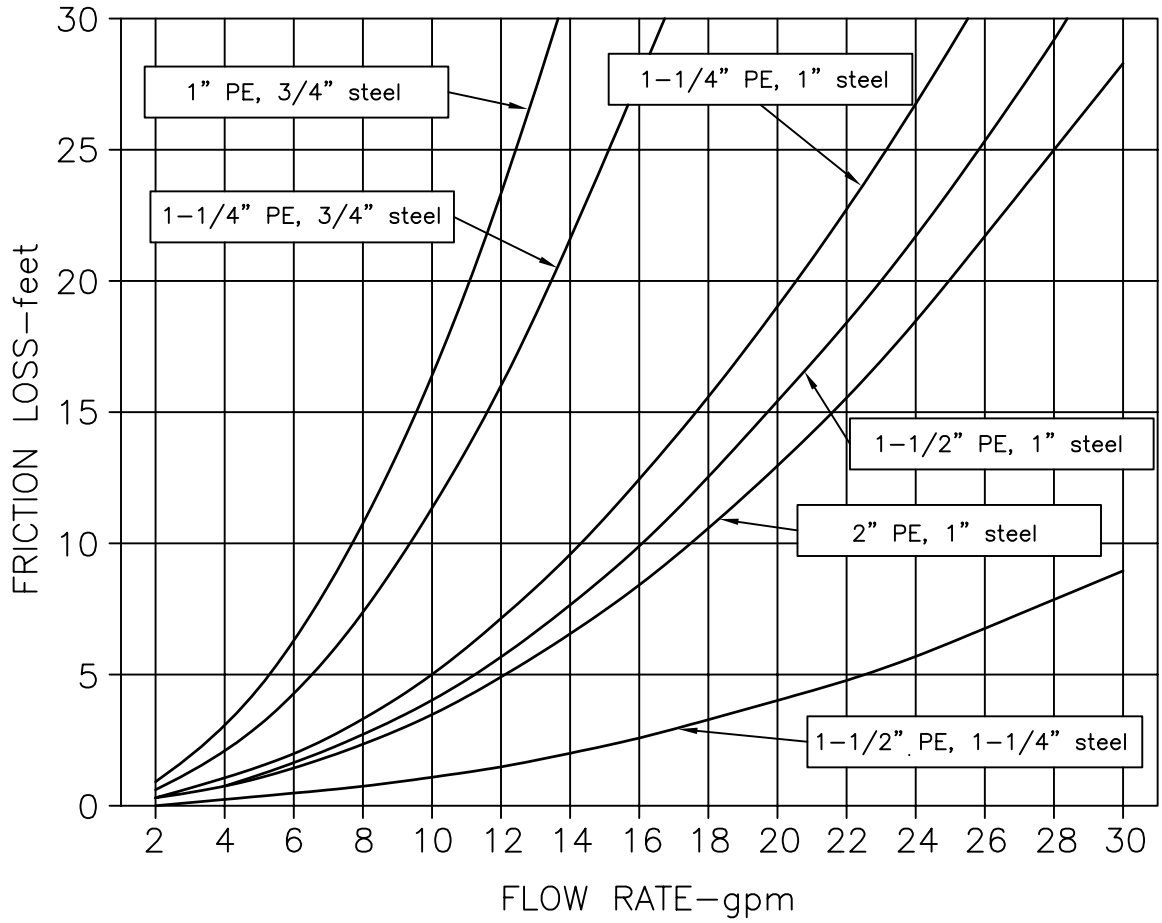
Figure 5.1 assumes the following conditions:

100 feet pump depth in well
PE pipe between pump and pressure tank
(100 ft + 25 ft to manhole/tank = 125 ft length of PE pipe)
15 feet of galvanized steel pipe at manhole
4 90 degree elbows in steel pipe
1 "T" in steel pipe
1 open gate valve in steel pipe
1 check valve in steel pipe

The friction loss in PE pipe is so low that well depths different than the assumed 100 feet will make little difference in total friction loss. If the total plumbing system is significantly different than assumed above, special calculations should be performed. If steel pipe is used to drop the pump in the well, special computations must be made.

It is becoming a more popular practice for submersible pumps to be suspended by schedule 80 PVC pipe with threaded connections. The friction loss in this installation would be similar to that for PE pipe.

Figure 5.1
ESTIMATED FRICTION LOSS AT WELL



Curve Type
(1) 1" PE connector pipe, 3/4" steel plumbing at tank
(2) 1–1/4" PE connector pipe, 3/4" steel plumbing at tank
(3) 1–1/4" PE connector pipe, 1" steel plumbing at tank
(4) 1–1/2" PE connector pipe, 1" steel plumbing at tank
(5) 2" PE connector pipe, 1" steel plumbing at tank
(6) 2–1/2" PE connector pipe, 1–1/4" steel plumbing at tank

Note:
The above chart is based on:
100 feet to water surface in well
PE connector pipe
15 feet of steel pipe
4 steel pipe elbows
1 steel "T"
1 gate valve in steel pipe
1 check valve in steel pipe

The following tables are based on friction loss by the Hazen - Williams formula. The form of the equation used is:

$H_f = (gpm/C)^{1.85185} \times 10.4057 / (d_i^{4.87037}) \times L$

C = Hazen-Williams friction loss factor
gpm = Flow rate in gallons per minute
d_i = Pipe inside diameter
L = Length of pipe segment (100-feet used incalculations).

The "C" factor used for PE and PVC plastic pipe is 135. Most research data shows that new PVC or PE has a "C" valve of 150. Missouri recommends using a C=135 to account for increasing resistance as the pipe ages. This will permit minor losses such as "snaking" laid pipe and a normal quantity of couplers, tees and valves to be ignored.

It is very important that the correct inside diameter be used. The inside diamter will vary depending on the type of pipe or tubing used. Other forms of the Hazen-Williams Formula are:

Velocity

$V = 1.318\ CR^{0.63} S^{0.54}$
$V = 0.550\ CD^{0.63} S^{0.54}$
$V = 0.115\ Cd^{0.63} S^{0.54}$

Flow

$Q = 16.66\ CR^{2.63} S^{0.54}$ $\quad q = 7427\ CR^{2.63} S^{0.54}$
$Q = 0.432\ CD^{2.63} S^{0.54}$ $\quad q = 193.9\ CD^{2.63} S^{0.54}$
$Q = 0.000627\ Cd^{2.63} S^{0.54}$ $\quad q = 0.281\ Cd^{2.63} S^{0.54}$

HEAD LOSS

$$HL = 0.600 \times \frac{V^{1.85}}{C^{1.85} R^{1.17}} \qquad HL = \frac{841500\, Q^{1.85}}{C^{1.85} d^{1.87}} \qquad HL = 0.00566 x \frac{Q^{1.85}}{C^{1.85} d^{1.87}}$$

$$HL = 3.04 \times \frac{V^{1.85}}{C^{1.85} D^{1.17}} \qquad HL = \frac{6.936 \times 10^{-8}\ xq^{1.85}}{C^{1.85}\ R^{1.87}} \qquad HL = \frac{10.47\, q^{1.85}}{C^{1.85}\ R^{4.87}}$$

$$HL = 54.66 \times \frac{V^{1.85}}{C^{1.85} d^{1.17}} \qquad HL = \frac{5.861 \times 10^{-5}\ xq^{1.85}}{C^{1.85} D^{4.87}} \qquad HL = \frac{4.72\, xQ^{1.85}}{C^{1.85} D^{1.87}}$$

Units

HL = Head Loss in feet
C = Flow Factor (dimensionally)
R = Hydraulic Radius in feet
S = Slope in feet per foot
D = Inside Diameter in feet
q = Flow Rate in gallons per minute
Q = Flow Rate in cubic feet per second

Table 5.4

PVC PIPE, SDR 26
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
			1.195 ID	1.532 ID	1.754 ID	2.193 ID	2.655 ID	3.230 ID
2.0			0.1790	0.0534	0.0276	0.0093	0.0037	0.0014
4.0			0.6461	0.1927	0.0997	0.0336	0.0132	0.0051
6.0			1.3691	0.4083	0.2112	0.0712	0.0280	0.0108
6.5			1.5878	0.4735	0.2450	0.0825	0.0325	0.0125
7.0			1.8214	0.5432	0.2810	0.0947	0.0373	0.0144
7.5			2.0696	0.6172	0.3193	0.1076	0.0424	0.0163
8.0			2.3323	0.6955	0.3598	0.1212	0.0478	0.0184
8.5			2.6094	0.7782	0.4026	0.1356	0.0535	0.0206
9.0			2.9008	0.8651	0.4475	0.1508	0.0594	0.0229
9.5			3.2063	0.9562	0.4946	0.1667	0.0657	0.0253
10.0			3.5258	1.0514	0.5439	0.1833	0.0722	0.0278
11.0			4.2064	1.2544	0.6489	0.2186	0.0862	0.0332
12.0			4.9418	1.4737	0.7624	0.2569	0.1012	0.0390
13.0			5.7314	1.7092	0.8842	0.2979	0.1174	0.0452
14.0			6.5745	1.9606	1.0143	0.3417	0.1347	0.0518
15.0			7.4705	2.2278	1.1525	0.3883	0.1530	0.0589
16.0			8.4188	2.5106	1.2988	0.4376	0.1725	0.0664
17.0			9.4191	2.8089	1.4531	0.4896	0.1930	0.0743
18.0			v>5 fps	3.1226	1.6154	0.5443	0.2145	0.0826
19.0			v>5 fps	3.4514	1.7855	0.6016	0.2371	0.0913
20.0			v>5 fps	3.7953	1.9634	0.6615	0.2607	0.1004

Hazen-Williams C = 135
ASTM-D-2241, PVC 1120, 1220 and 2120
Pressure Rating is 160 psi @ 73.4 F (72% of PR = 115 psi)

Table 5.5

PVC PIPE, SDR 21
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
		0.930 ID	1.189 ID	1.502 ID	1.720 ID	2.149 ID	2.601 ID	3.166 ID
2.0		0.6070	0.1834	0.0588	0.0304	0.0103	0.0041	0.0016
4.0		2.1910	0.6622	0.2122	0.1097	0.0371	0.0146	0.0056
6.0		4.6423	1.4030	0.4496	0.2323	0.0785	0.0310	0.0119
6.5		5.3840	1.6272	0.5214	0.2695	0.0911	0.0360	0.0138
7.0		6.1760	1.8666	0.5981	0.3091	0.1045	0.0412	0.0158
7.5		7.0177	2.1210	0.6796	0.3512	0.1187	0.0469	0.0180
8.0		7.9086	2.3902	0.7659	0.3958	0.1338	0.0528	0.0203
8.5		8.8482	2.6742	0.8569	0.4428	0.1497	0.0591	0.0227
9.0		9.8362	2.9728	0.9525	0.4923	0.1664	0.0657	0.0252
9.5		10.8720	3.2858	1.0528	0.5441	0.1839	0.0726	0.0279
10.0		11.9554	3.6133	1.1577	0.5983	0.2023	0.0798	0.0306
11.0		v>5 fps	4.3107	1.3812	0.7138	0.2413	0.0952	0.0366
12.0		v>5 fps	5.0644	1.6227	0.8387	0.2835	0.1119	0.0430
13.0		v>5 fps	5.8736	1.8820	0.9727	0.3288	0.1298	0.0498
14.0		v>5 fps	6.7376	2.1588	1.1157	0.3772	0.1489	0.0571
15.0		v>5 fps	7.6559	2.4531	1.2678	0.4286	0.1691	0.0649
16.0		v>5 fps	8.6278	2.7645	1.4287	0.4830	0.1906	0.0732
17.0		v>5 fps	9.6529	3.0929	1.5985	0.5404	0.2133	0.0819
18.0		v>5 fps	v>5 fps	3.4383	1.7770	0.6007	0.2371	0.0910
19.0		v>5 fps	v>5 fps	3.8004	1.9641	0.6640	0.2621	0.1006
20.0		v>5 fps	v>5 fps	4.1790	2.1598	0.7301	0.2882	0.1106

Hazen-Williams C = 135
ASTM-D-2241, PVC 1120, 1220 and 2120
Pressure Rating is 200 psi @ 73.4 F (72% of PR = 144 psi)

Table 5.6

PVC PIPE, SDR 17
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
		0.926 ID	1.161 ID	1.464 ID	1.676 ID	2.095 ID	2.537 ID	3.088 ID
2.0		0.6199	0.2060	0.0666	0.0345	0.0116	0.0046	0.0018
4.0		2.2375	0.7437	0.2404	0.1244	0.0420	0.0165	0.0063
6.0		4.7408	1.5757	0.5093	0.2636	0.0889	0.0350	0.0134
6.5		5.4982	1.8275	0.5907	0.3057	0.1031	0.0406	0.0156
7.0		6.3070	2.0963	0.6776	0.3507	0.1183	0.0466	0.0179
7.5		7.1666	2.3820	0.7699	0.3985	0.1344	0.0529	0.0203
8.0		8.0764	2.6844	0.8677	0.4491	0.1515	0.0596	0.0229
8.5		9.0360	3.0033	0.9708	0.5024	0.1695	0.0667	0.0256
9.0		10.0449	3.3386	1.0791	0.5585	0.1884	0.0742	0.0285
9.5		11.1027	3.6902	1.1928	0.6173	0.2082	0.0820	0.0315
10.0		12.2090	4.0579	1.3116	0.6788	0.2290	0.0901	0.0346
11.0		v>5 fps	4.8413	1.5648	0.8099	0.2732	0.1075	0.0413
12.0		v>5 fps	5.6877	1.8384	0.9515	0.3209	0.1263	0.0485
13.0		v>5 fps	6.5965	2.1322	1.1035	0.3722	0.1465	0.0563
14.0		v>5 fps	7.5668	2.4458	1.2658	0.4270	0.1681	0.0645
15.0		v>5 fps	8.5981	2.7791	1.4383	0.4851	0.1910	0.0733
16.0		v>5 fps	9.6896	3.1320	1.6209	0.5467	0.2152	0.0826
17.0		v>5 fps	v>5 fps	3.5041	1.8135	0.6117	0.2408	0.0925
18.0		v>5 fps	v>5 fps	3.8953	2.0160	0.6800	0.2677	0.1028
19.0		v>5 fps	v>5 fps	4.3055	2.2283	0.7516	0.2959	0.1136
20.0		v>5 fps	v>5 fps	4.7346	2.4503	0.8265	0.3253	0.1249

Hazen-Williams C = 135
ASTM-D-2241, PVC 1120, 1220 and 2120
Pressure Rating is 250 psi @ 73.4 F (72% of PR = 180 psi)

Table 5.7

PVC PIPE, SDR 13.5
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
	0.716 ID	0.894 ID	1.121 ID	1.414 ID	1.654 ID	2.023 ID	2.449 ID	2.982 ID
2.0	2.1692	0.7357	0.2444	0.0789	0.0368	0.0138	0.0054	0.0021
4.0	7.8301	2.6555	0.8821	0.2847	0.1327	0.0498	0.0196	0.0075
6.0	16.5905	5.6265	1.8691	0.6032	0.2811	0.1054	0.0416	0.0159
6.5	v>5 fps	6.5255	2.1677	0.6996	0.3260	0.1223	0.0482	0.0185
7.0	v>5 fps	7.4853	2.4866	0.8025	0.3740	0.1402	0.0553	0.0212
7.5	v>5 fps	8.5055	2.8255	0.9119	0.4250	0.1594	0.0628	0.0241
8.0	v>5 fps	9.5853	3.1842	1.0277	0.4789	0.1796	0.0708	0.0271
8.5	v>5 fps	10.7241	3.5625	1.1498	0.5358	0.2009	0.0792	0.0304
9.0	v>5 fps	11.9215	3.9603	1.2782	0.5956	0.2234	0.0881	0.0338
9.5	v>5 fps	13.1769	4.3774	1.4128	0.6584	0.2469	0.0973	0.0373
10.0	v>5 fps	v>5 fps	4.8135	1.5535	0.7240	0.2715	0.1070	0.0410
11.0	v>5 fps	v>5 fps	5.7427	1.8534	0.8637	0.3239	0.1277	0.0489
12.0	v>5 fps	v>5 fps	6.7468	2.1775	1.0147	0.3805	0.1500	0.0575
13.0	v>5 fps	v>5 fps	7.8248	2.5254	1.1768	0.4413	0.1740	0.0667
14.0	v>5 fps	v>5 fps	8.9758	2.8968	1.3500	0.5062	0.1996	0.0765
15.0	v>5 fps	v>5 fps	10.1990	3.2916	1.5339	0.5752	0.2268	0.0869
16.0	v>5 fps	v>5 fps	v>5 fps	3.7095	1.7287	0.6483	0.2556	0.0980
17.0	v>5 fps	v>5 fps	v>5 fps	4.1503	1.9341	0.7253	0.2860	0.1096
18.0	v>5 fps	v>5 fps	v>5 fps	4.6137	2.1500	0.8063	0.3179	0.1218
19.0	v>5 fps	v>5 fps	v>5 fps	5.0995	2.3764	0.8912	0.3514	0.1347
20.0	v>5 fps	v>5 fps	v>5 fps	5.6076	2.6132	0.9800	0.3864	0.1481

Hazen-Williams C = 135
ASTM-D-2241, PVC 1120, 1220 and 2120
Pressure Rating is 315 psi @ 73.4 F (72% of PR = 227 psi)

Table 5.8

PVC (IPS) PIPE, SCHEDULE 40
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch 600 PR 0.622 ID	3/4 inch 480 PR 0.824 ID	1 inch 450 PR 1.049 ID	1-1/4 inch 370 PR 1.380 ID	1-1/2 inch 330 PR 1.610 ID	2 inch 280 PR 2.067 ID	2-1/2 inch 300 PR 2.469 ID	3 inch 260 PR 3.048 ID
2.0	4.3052	1.0943	0.3377	0.0888	0.0419	0.0124	0.0052	0.0019
4.0	15.5401	3.9501	1.2189	0.3205	0.1513	0.0448	0.0189	0.0068
6.0	32.9268	8.3695	2.5825	0.6792	0.3206	0.0949	0.0399	0.0143
6.5	v>5 fps	9.7067	2.9952	0.7877	0.3718	0.1101	0.0463	0.0166
7.0	v>5 fps	11.1346	3.4358	0.9035	0.4265	0.1263	0.0531	0.0190
7.5	v>5 fps	12.6520	3.9040	1.0267	0.4846	0.1435	0.0604	0.0216
8.0	v>5 fps	14.2582	4.3996	1.1570	0.5461	0.1617	0.0681	0.0244
8.5	v>5 fps	15.9523	4.9224	1.2945	0.6110	0.1809	0.0761	0.0273
9.0	v>5 fps	17.7334	5.4720	1.4390	0.6792	0.2011	0.0846	0.0303
9.5	v>5 fps	19.6009	6.0482	1.5905	0.7507	0.2223	0.0936	0.0335
10.0	v>5 fps	v>5 fps	6.6509	1.7490	0.8256	0.2445	0.1029	0.0369
11.0	v>5 fps	v>5 fps	7.9347	2.0867	0.9849	0.2917	0.1227	0.0440
12.0	v>5 fps	v>5 fps	9.3220	2.4515	1.1571	0.3427	0.1442	0.0517
13.0	v>5 fps	v>5 fps	10.8115	2.8432	1.3420	0.3974	0.1672	0.0599
14.0	v>5 fps	v>5 fps	12.4018	3.2614	1.5394	0.4559	0.1918	0.0688
15.0	v>5 fps	v>5 fps	14.0920	3.7059	1.7492	0.5180	0.2180	0.0781
16.0	v>5 fps	v>5 fps	v>5 fps	4.1764	1.9713	0.5838	0.2457	0.0881
17.0	v>5 fps	v>5 fps	v>5 fps	4.6726	2.2055	0.6531	0.2749	0.0985
18.0	v>5 fps	v>5 fps	v>5 fps	5.1943	2.4517	0.7260	0.3055	0.1095
19.0	v>5 fps	v>5 fps	v>5 fps	5.7413	2.7099	0.8025	0.3377	0.1210
20.0	v>5 fps	v>5 fps	v>5 fps	6.3134	2.9799	0.8825	0.3714	0.1331

Hazen-Williams C = 135
ASTM-D-1785, PVC 1120, 1220 and 2120
Pressure Rating (PR) @ 73 F varies with pipe diameter and is shown with psi units

Table 5.9

PVC (IPS) PIPE, SCHEDULE 80
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch 850 PR 0.546 ID	3/4 inch 690 PR 0.742 ID	1 inch 630 PR 0.957 ID	1-1/4 inch 520 PR 1.278 ID	1-1/2 inch 470 PR 1.500 ID	2 inch 400 PR 1.939 ID	2-1/2 inch 420 PR 2.323 ID	3 inch 370 PR 2.900 ID
2.0	8.1216	1.8233	0.5280	0.1291	0.0592	0.0169	0.0070	0.0024
4.0	29.3161	6.5814	1.9059	0.4659	0.2136	0.0612	0.0254	0.0086
6.0	62.1157	13.9448	4.0383	0.9872	0.4525	0.1296	0.0538	0.0182
6.5	v>5 fps	16.1729	4.6835	1.1449	0.5248	0.1503	0.0623	0.0212
7.0	v>5 fps	18.5519	5.3725	1.3133	0.6020	0.1724	0.0715	0.0243
7.5	v>5 fps	21.0803	6.1047	1.4923	0.6840	0.1959	0.0813	0.0276
8.0	v>5 fps	23.7564	6.8796	1.6817	0.7709	0.2208	0.0916	0.0311
8.5	v>5 fps	26.5790	7.6970	1.8815	0.8624	0.2470	0.1025	0.0348
9.0	v>5 fps	29.5466	8.5564	2.0916	0.9587	0.2746	0.1139	0.0387
9.5	v>5 fps	32.6581	9.4575	2.3119	1.0597	0.3035	0.1259	0.0427
10.0	v>5 fps	v>5 fps	10.3999	2.5422	1.1653	0.3338	0.1384	0.0470
11.0	v>5 fps	v>5 fps	12.4074	3.0330	1.3902	0.3982	0.1652	0.0561
12.0	v>5 fps	v>5 fps	14.5767	3.5633	1.6333	0.4678	0.1940	0.0659
13.0	v>5 fps	v>5 fps	16.9058	4.1326	1.8943	0.5426	0.2250	0.0764
14.0	v>5 fps	v>5 fps	19.3926	4.7405	2.1729	0.6224	0.2582	0.0876
15.0	v>5 fps	v>5 fps	22.0355	5.3866	2.4690	0.7072	0.2933	0.0996
16.0	v>5 fps	v>5 fps	v>5 fps	6.0704	2.7825	0.7970	0.3306	0.1122
17.0	v>5 fps	v>5 fps	v>5 fps	6.7916	3.1131	0.8917	0.3698	0.1255
18.0	v>5 fps	v>5 fps	v>5 fps	7.5500	3.4607	0.9912	0.4111	0.1396
19.0	v>5 fps	v>5 fps	v>5 fps	8.3450	3.8251	1.0956	0.4544	0.1542
20.0	v>5 fps	v>5 fps	v>5 fps	9.1766	4.2063	1.2048	0.4997	0.1696

Hazen-Williams C = 135
ASTM-D-1785, PVC 1120, 1220 and 2120, Non-threaded pipe
Pressure Rating (PR) @ 73 F varies with pipe diameter and is shown with psi units

Table 5.10

PE PIPE, SIDR-PR
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
	0.622 ID	0.824 ID	1.049 ID	1.380 ID	1.610 ID	2.067 ID	2.469 ID	3.048 ID
2.0	4.3052	1.0943	0.3377	0.0888	0.0419	0.0124	0.0052	0.0019
4.0	15.5401	3.9501	1.2189	0.3205	0.1513	0.0448	0.0189	0.0068
6.0	32.9268	8.3695	2.5825	0.6792	0.3206	0.0949	0.0399	0.0143
6.5	v>5 fps	9.7067	2.9952	0.7877	0.3718	0.1101	0.0463	0.0166
7.0	v>5 fps	11.1346	3.4358	0.9035	0.4265	0.1263	0.0531	0.0190
7.5	v>5 fps	12.6520	3.9040	1.0267	0.4846	0.1435	0.0604	0.0216
8.0	v>5 fps	14.2582	4.3996	1.1570	0.5461	0.1617	0.0681	0.0244
8.5	v>5 fps	15.9523	4.9224	1.2945	0.6110	0.1809	0.0761	0.0273
9.0	v>5 fps	17.7334	5.4720	1.4390	0.6792	0.2011	0.0846	0.0303
9.5	v>5 fps	19.6009	6.0482	1.5905	0.7507	0.2223	0.0936	0.0335
10.0	v>5 fps	v>5 fps	6.6509	1.7490	0.8256	0.2445	0.1029	0.0369
11.0	v>5 fps	v>5 fps	7.9347	2.0867	0.9849	0.2917	0.1227	0.0440
12.0	v>5 fps	v>5 fps	9.3220	2.4515	1.1571	0.3427	0.1442	0.0517
13.0	v>5 fps	v>5 fps	10.8115	2.8432	1.3420	0.3974	0.1672	0.0599
14.0	v>5 fps	v>5 fps	12.4018	3.2614	1.5394	0.4559	0.1918	0.0688
15.0	v>5 fps	v>5 fps	14.0920	3.7059	1.7492	0.5180	0.2180	0.0781
16.0	v>5 fps	v>5 fps	v>5 fps	4.1764	1.9713	0.5838	0.2457	0.0881
17.0	v>5 fps	v>5 fps	v>5 fps	4.6726	2.2055	0.6531	0.2749	0.0985
18.0	v>5 fps	v>5 fps	v>5 fps	5.1943	2.4517	0.7260	0.3055	0.1095
19.0	v>5 fps	v>5 fps	v>5 fps	5.7413	2.7099	0.8025	0.3377	0.1210
20.0	v>5 fps	v>5 fps	v>5 fps	6.3134	2.9799	0.8825	0.3714	0.1331

PE MATERIALS AND PRESSURE RATINGS

Material	SIDR	PR (psi)	72% PR (psi)
3408	15	100	72
3306 & 3406	15	80	58
3408	11.5	125	90
3306 & 3406	11.5	100	72
3408	9	160	115
3306 & 3406	9	125	90
3408	7	200	144
3306 & 3406	7	160	115
3408	5.3	250	180
3306 & 3406	5.3	200	144

Hazen-Williams C = 135
ASTM-D-2239, PE Pipe
Pressure Rating (PR) @ 73 F varies with pipe material

5.10 PVC PIPE FITTINGS

Schedule 40 and 80 solvent weld and threaded fittings are covered by the following ASTM standards:

D2624 - Threaded Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 80

D2466 - Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 40

D2467 - Socket-Type Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 80

These standards deal mainly with workmanship, materials, dimensions, tolerances, and testing. There are no pressure rating standards for PVC fittings in the ASTM specifications. The only pressure standards specified are for burst pressure.

One analysis, based on very limited real data, proposes the upper limit working pressures for Schedule 40 and 80 PVC fittings as tabulated in Table 5.11. Use this as a general guide only. Actual allowable working pressures may vary widely with field conditions, particularly the frequency and degree of surge pressures anticipated. On high pressure pipelines, metal or other alternative type fittings may be needed.

Table 5.11
Estimated Upper Limit Working Pressures for
Schedule 40 and Schedule 80 PVC Fittings

Nominal Diameter (in)	Outside Diameter (in)	Schedule 40 Pressure Rating Burst (psi)	Schedule 40 Pressure Rating Working (psi)	Schedule 80 Pressure Rating Burst (psi)	Schedule 80 Pressure Rating Working (psi)
1/2	0.840	1910	358	2720	509
3/4	1.050	1540	289	2200	413
1	1.315	1440	270	2020	378
1-1/4	1.660	1180	221	1660	312
1-1/2	1.900	1060	198	1510	282
2	2.375	890	166	1290	243
2-1/2	2.875	970	182	1360	255
3	3.500	840	158	1200	225